

# Unmanned Aircraft Systems Integration in the New York Terminal Area



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Sincerely,

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## Abstract

The New York City area is home to the busiest airspace in the world. Currently, over 4,000 scheduled arrivals and departures occur daily into and out of the five major airports surrounding New York City. These airports include Newark Liberty International Airport, John F. Kennedy International Airport, LaGuardia Airport, Teterboro Airport, and Westchester County Airport. With the expected rise in commercial aviation due to increased demand, the airspace above New York will be increasingly congested and strenuous on the air traffic controllers tasked with airspace safety and efficiency. As new FAA NextGen technology becomes standard, more efficient and quieter approaches will be possible. This is due to performance based navigation which allows a continuous descent to landing. With these advances, new routes are possible to increase operations while reducing delays. The rise in unmanned aerial systems and their integration into domestic airspace within the coming years will also introduce a new variable into a very congested airspace over the New York area. By determining where UAS flight will cause the least interruption of current operations, within the scope of both aviation safety and security, the integration of UAS in the tri-state area may open new markets in the sky while still allowing the existing transportation network to operate safely and efficiently. By analyzing current traffic flow patterns around New York City, the design of more efficient routes and the possibility of future UAS integration become achievable objectives necessary for continued smooth operation of all aircraft in the World's busiest airspace.

# Introduction

Unmanned aircraft systems are aircraft without a pilot onboard which operates through a controller on the ground via wireless communication methods. These systems have been used extensively in military roles throughout the preceding two decades. As military conflicts wind down, more military UAS aircraft and their operators are conducting training operations in special use airspace within the national airspace system. Concurrently, UAS technology has rapidly grown



*Figure 1. A drone flying over Brooklyn.*

among civilian users and commercial enterprises, realizing the potential UAS has within a civilian market, as a useful tool. Identified uses of civilian UAS technology include photography, cartography, media reporting, and search and rescue. Currently, UAS operation is limited to government entities and the Department of Defense operating under Certificates of Authorization (COA) obtained through the

Federal Aviation Administration. The DoD and FAA have realized that seamless UAS integration into the National Airspace System is a necessity for emerging markets for UAS and safety for all future flight operations. While required changes and general UAS integration plans have been proposed by both the FAA and DoD, no detailed analysis of UAS operation has occurred for any major metropolitan areas, such as New York City (Federal Aviation Administration, 2013).

The New York Terminal Area is the busiest airspace in the United States, accommodating over 4,000 scheduled arrivals and departures per day. This airspace is also home to a plethora of general aviation airports which are essential to private aviation in New York and New Jersey. This airspace also contains the heavily travelled Hudson River and East River exclusion areas, low altitude corridors around New York City which offer airspace passage and local operations to both fixed wing aircraft and rotorcraft. While the New York terminal area is congested, it also contains New York City, an area that has required increased scrutiny of aircraft, due to 9/11, in the interest of national security. These factors make the New York Terminal Area one of the most complex airspace systems in the world (National Business Aviation Association, 2011).

The FAA has also done analysis into new technology to increase safety and efficiency in the national airspace system. This program, called NextGen, calls for implementing new air traffic

routes for arriving and departing traffic based on new technology which will allow safer, more efficient travel. These new routes and technology, according to the FAA, will be able to handle more flights in less time, reduce delays, and make the skies safer for all air traffic. While UAS integration is a part of the final NextGen project, it has not been analyzed in detail for any specific airspace, as testing is currently being conducted between manned and unmanned aircraft interaction at six test sites around the United States (Federal Aviation Administration, 2007).

The purpose of this analysis was to create a plan for UAS integration within the New York Terminal Area based on DoD recommendations and FAA NextGen projected technology and air route changes. This report will begin the process of tailoring UAS technology, required technology, and new procedures into the existing and projected airspace of New York, a complex and dynamic flight environment which demands safety and efficiency.

# Research

## Airspace in the United States

United States Airspace is defined as the navigable air above the United States as well as 12 nautical miles over water. The airspace in the United States was entirely uncontrolled in the pre-World War I era. After the war, improvements in radio communication and navigation allowed aerial guidance through technology, permitting night flight and instrument flying. Air traffic was tracked and monitored through pilot communications and plotting positions on aerial navigation charts. After World War II, jets began to dominate the skies and radar was introduced. Radar is radio detection and ranging which allowed real time interrogation of a plane's distance. In 1958, two commercial aircraft collided over the Grand Canyon, prompting the creation of the Federal Aviation Administration and increased funding towards upgraded air traffic control equipment. In 1990, the International Civil Aviation Organization standardized new classes of airspace with different entry, separation, and communication requirements. The United States adopted this format with a few modifications to accommodate American aviation.



Airspace is divided into seven classes, each with unique operating requirements and procedures. Class A airspace is all airspace over the contiguous United States from 18,000 ft. MSL

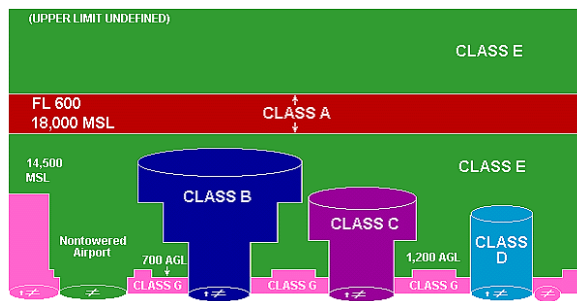


Figure 2. Diagram of various airspace classes.

(Mean Sea Level) to 60,000 ft. MSL. Entry requirements include an instrument flight rating and filed instrument flight plan. In Class A airspace, the aircraft and its pilot are under positive control and separation by air traffic control. Class B airspace is specifically tailored airspace, usually up to 10,000 ft. MSL, around the nation's busiest

airports in terms of Instrument Flight Rules (IFR) operations or passenger enplanements. Requirements to enter Class B airspace include, private pilot certificate or student pilot with endorsement, specific clearance to enter the class B airspace, and one mile visibility while remaining clear of clouds. Class C airspace is airspace going up to 4,000 ft. MSL dictated by a towered airport and an accompanied approach control. Two way radio communication and a mode C transponder are required for entry into class C airspace. Class D airspace is a cylinder, usually 5 nautical miles in diameter around a towered airport. This cylinder often extends up to 2,500 ft. MSL. The only entry requirement is two way radio communication. Class E airspace is any airspace that is controlled, but is not Class A, Class B, Class C, or Class D airspace. There are no specific operating requirements for Class E airspace. Class G airspace is uncontrolled airspace that is not designated Class A, B, C, D, or E airspace. There are no operational requirements for aircraft in Class G airspace. The last type of airspace is special use airspace. This includes prohibited, restricted, warning, alert, and controlled firing areas, as well as military operations areas. These airspaces limit or ban all nonparticipating aircraft during active periods due to flight hazards and national security. Temporary Flight Restrictions (TFR) allow the FAA to temporarily limit flight activity that would be hazardous to national security. Space operations, disaster relief, and high capacity events are included under this definition (U.S. Department of Transportation/Federal Aviation Administration, 2008).

Flight is broken down into two categories based upon conditions of flight. Instrument Flight Rules (IFR) allow a pilot to operate in low visibility and adverse weather conditions. This is due to positive control by air traffic control at all times to maintain separation and obstacle clearance. Visual Flight Rules (VFR) may or may not operate with the assistance of air traffic



control, however the pilot in command is fully responsible to see and avoid other aircraft and obstacles during the flight. VFR operations are limited to below 18,000 ft. MSL and certain weather minimums depending on the airspace in which it is operating. The main difference in these two flight regimes is positive control by air traffic control during the entire flight for all IFR flights. Most commercial air traffic operates IFR within the United States. Private air traffic operates a mix of IFR and VFR traffic depending on the purpose of flight (FAR/AIM 2012).

## History of UAS

An unmanned aerial system (UAS), is an unmanned aircraft and its included support equipment, control station, data links, telemetry, communications and navigation equipment, and all other equipment necessary to properly and safely operate. Other terms were previously used to identify unmanned aircraft, such as Remotely Operated aircraft, remotely piloted vehicle, and unmanned aerial vehicle, but the most current and complete title is unmanned aerial systems. The unmanned aircraft can be either flown by a pilot at a remote ground control station, or autonomously by on-board computer systems. Previously looked at mostly for its military applications, UAS has an increasingly broad potential for other civil functions.

Unmanned aircraft came to existence with extremely primitive technology, yet it shaped a future of advancement. Austrians attacked Venice during World War I with unmanned balloons landed with explosives, directed solely on favorable winds. It wasn't until after the First World War that the first pilotless aircraft was created. These were called "flying bombs", effectively being the modern day cruise missile. These missiles were sporadic and unreliable, but the technology attracted worldwide attention.



*Figure 3. A Radio Controlled target drone used in World War II for anti-aircraft training.*

During World War II, remote control planes with wing spans of under fifteen feet were used to train anti-aircraft gunners in the US Army. Soon after, the US Navy created the N2C-2 drone that was remotely controlled by other aircraft. Thousands of full sized anti-aircraft target drones were being made with radio

controlled versions of old modified civil and military aircraft. Remote control B-17 and B-24 bombers were used for a short time as, basically, large scale aerial torpedoes. It wasn't until the

Naval Aircraft Factory produced the TDN-1 that the first assault drones saw moderate success, despite its almost nonexistent usage in the war.

UAS had a number of uses through the cold war. Target drones used in training operations continued to evolve and advance, and eventually large scale target drones were used as decoys to penetrate enemy airspaces. American aircraft converted into drones were eventually used to collect nuclear data by flying over radioactive clouds, test sites, and shockwaves. Drones were most successfully used in combat for reconnaissance, often sending information and then self-destructing after the mission. After the shooting down of U-2 pilot Francis Gary Powers, US intensified their research into stealth surveillance drones. Eventually used in the middle of the Vietnam War, large transportation aircraft would drop smaller reconnaissance drones from its wings which would deploy parachutes after their mission to be collected by helicopters (United States Department of Defense, 2014).

Today, UAS have a plethora of wartime benefits. The usage of drones wasn't universally accepted until the Israeli Air Force, the leading developers of UAV technology, effectively shutting down the Syrian Air Force with drones. UAV's are now produced in a variety of sizes to fit the need of each mission or duty. They can be used in combat, as seen in conflicts such as Operation Iraqi Freedom, as well as "high-altitude long-endurance" real-time surveillance. There is also a variety of small scale drones that can be hand launched by ground soldiers in the field. UAS is also applied to a number of fields outside military applications, such as border patrol, search and rescue, and surveillance (PBS, 2002).

## UAS Applications



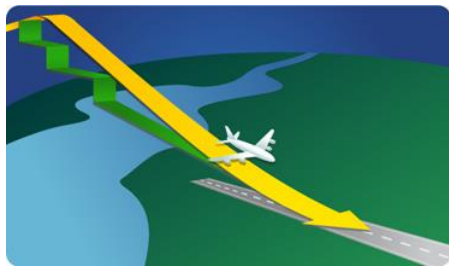
*Figure 4. United States Customs and Border Protection unmanned aerial vehicles used in border surveillance.*

As UAS technology progresses, its application are beginning to turn from strictly wartime use, to broader and more domestic operations. Some of these functions include exploration, cartography, photography, forest fire detection, search and rescue, border patrol, disaster relief, and many more. Specifically to the New York Area, most UAS operations would deal with commercial and media affairs. For example, aerial surveillance can be used with smaller, cheaper,

and more nimble UAS for roadwork, building security, or mapping. This would be particularly helpful with New York City's tall building, extensive roads, and generally populous area. These smaller UAS could also be used for media coverage in events, road traffic, or emergency situations to be broadcasted on television, eliminating the use for full-scale news helicopters. In addition, drones could become extremely popular in sports photography and cinematography. With the Meadowlands Sports Complex and other New York-based sports stadiums in the area, UAS could be a much more effective and safer method of sports coverage. Finally, in times of natural disasters, such as Hurricane Sandy, UAS equipped with infrared cameras or radar detection would easily be able to locate distressed citizens and conduct search and rescue missions.

## Next Generation Air Transportation System

Next Generation Air Transportation System, or NextGen, is a series of inter-linked programs, systems, and policies that implement advanced technologies and capabilities to dramatically change the way the current aviation system is operated. NextGen is satellite based and relies on a network to share information and digital communications so all users of the system



*Figure 5. A graphical depiction of a NextGen approach slope (yellow) with a current approach slope (red).*

are aware of other user's precise locations (Destination 2025). Overall, NextGen will completely change the way commercial aircraft operate with its advanced satellite-based technology. NextGen is a progressive installation and is undergoing constant expansion in the United States. This satellite technology will allow air traffic control and pilots to have greater situational awareness, instead of relying on half century old navigation techniques, such as LORAN or VOR navigation. Thus, flight plans turn from indirect routes to effective and precise paths that allows pilots to reach airports faster and more predictably. With more effective flights comes shorter flight times and economic saving, benefiting the passenger as well. Flights are no longer limited to preset routes, and each plane will have its own unique, satellite produced flight path and direction based on real-time collected data, such as wind, traffic, destination, and weather. Upon descent, planes are given a place in line for landing hundreds of miles before reaching the airport. In addition, pilots are required to fly

continuous descent approaches to reduce carbon emissions, fuel consumption, and noise. Just in the New York area, NextGen has allowed for a transition towards performance based navigation, improved approaches and low visibility operations, and improved multiple runway operations. By 2030, it is expected that there will be 1.2 billion passengers per year and over 60,000 flights per day. It is predicted that by that time, NextGen will have saved \$123 billion, enough to buy 400 NextGen-equipped jumbo jets. All in all, NextGen creates a safer, faster, and greener future for air travel while reducing delays and boosting passenger experience.

NextGen is extremely important to UAS integration with the National Airspace System (NAS) because all potential concepts for the widespread integration of UAS must comply with the future environment of NextGen. Also, the levels of safety upheld for manned aircraft within the NAS and solidified by NextGen will be equally shared for UAS in collision avoidance and self-separation. In aircraft collision avoidance, pilots are advised to follow a “see and avoid” concept, in which one must remain vigilant and alert of other aircraft or traffic movement in the area, regardless of aircraft type or flight rules being used. The FAA has always required strict separation of aircraft, which is closely monitored by Air Traffic Control to decrease wake turbulence and midair collisions. Separation distance is dependent on a variety of factors, but vertical separation is mostly between 1000-2000 feet and horizontal separation is mostly between 3 to 10 nautical miles (United States Department of Transportation/Federal Aviation Administration/Flight Standards Service, 2004). Some system and procedure changes may be necessary to fit the specific needs of unmanned aircraft, but no major changes will be necessary to NAS or future NextGen implementation plans.

## **Automatic Dependent Surveillance-Broadcast**

The Automatic dependent surveillance-broadcast, also known as ADS-B, is a system for aircraft in which it determines and broadcasts its own position through satellite. GPS signals along with aircraft avionics send the aircraft location to the ground receivers, which then transmit the information to controllers and pilot. This not only allows other pilots to be more aware of their surroundings, but also allows air traffic control ground stations to accurately vector flights and

control airspaces. ADS-B is one of the major components to the FAA's plan to overhaul the current radar-based system to a state-of-the-art systems, and is a key component to the Next Generation Air Transportation System. This technology would enable UAS to better autonomously detect traffic, while also easing collision avoidance for the human controller.

## **Transponder**

A transponder is an electric device that wirelessly produces a response when it receives a radio-frequency interrogation. These interrogations take information and then automatically make a radio wave at a predetermined frequency. Transponders were first used during World War II to identify enemies through secret interrogation frequencies. Transponders can be found in virtually all aircraft today, and are used for identification on air traffic control radar and collision avoidance. Air traffic control will commonly tell a pilot to “squawk” a certain code over the radio; the pilot will select the code on his or her transponder so the controller can currently identify the aircraft over radar. There are various modes of transponder, each with varying amounts of information, with some models required for certain airspace. A transponder is absolutely necessary for all UAS because, currently, almost all airworthy aircraft carry transponders. Particularly in congested airspace, transponders must be utilized for controller radar in identifying and vectoring aircraft.

## **Sense and Avoid Technology**

The FAA has based most of its midair collision systems off of the eyesight of the human pilot, also known as ‘see and avoid’, even when the presence of more advanced technology, such as transponders or radar systems are present. This has been an effective and safe way of traversing the sky for many years. However, with the addition of military, civilian, and commercial applications for UAS, the airspace becomes more crowded and difficult to maneuver through. UAS do not have the luxury of a human pilot's ‘see safety’ thus it becomes necessary that an active detect, sense, and avoid System is researched and adopted in the near future. The act of sensing, detecting, and avoiding, to the FAA, are very specific definitions; each are similar to the human

side of ‘see and avoid, but must act autonomously (unless under partial human control). To detect is to ascertain that there is something in the airspace, which in turn does not imply that the object has been identified. This object is simply an obscuration in the airspace, whether that be a small bird or a full sized aircraft. For this reason, the operational definition of detect, for a UAS, is to determine through some technology that something is in the airspace. For sensing, the UAS must determine if the object is a threat, and run through a series of algorithms to make a decision, without the human pilots reasoning. Lastly, avoidance is the act of moving away from a threat, which can be done after autonomous computed decisions or human input. There are currently a number of technologies and systems currently being developed that would lead to a major breakthrough of and widespread utilization of ‘sense and avoid’ for UAS. Collision avoidance and safety is the primary concern to the FAA, thus this field of technology for UAS is top priority for UAS integration in NAS.

## Department of Defense UAS Integration Strategy

The United States Department of Defense (DoD) currently stands in a lead position for unmanned aerial system (UAS) integration for public aircraft; specifically because of its wide operation of UAS, partnership with the FAA, NASA, and Department of Homeland Security,



*Figure 6. Department Of Defense unmanned aerial vehicle*

control of DoD aircraft and airspace, and national regulation of aircraft and pilots. Recognizing the integral impact of unmanned aerial system (UAS) in United States Military and Government Operations, the DoD has begun to plan for UAS integration into the National Air Space System. The domestic operations of UAS, such as Homeland Security, Homeland Defense, and

Defense Support of Civil Authorities, makes the safe and routine access to the NAS a top priority. The DoD plans on increasing domestic UAS roles in border and port surveillance, maritime operation, and disaster or special event support. The factors of integration the DoD highlights include UAS types, classes and types of airspace, Programs of Record (POR) requirements, available technologies, and specific mission needs. The integration plan entails the use of new



airspace technology, such as Next Generation Air Transportation System, as well as creating a full set of new regulations and policies specific to safe and efficient UAS access to the NAS.

One of the major problems that the DoD outlines as a call for integration is that the NAS has not kept up with UAS. While general manned aviation grew over the past century, airspace regulations and air traffic procedures progressed to match the technology of the airplanes. However, UAS has seen a growth so rapid that NAS has failed to support its safe operation. To support the broad domestic military and civil call for UAS, there must be actions made to successfully integrate. Although the requirements for conducting NAS operations are specifically categorized based on the type of flight operation or class of civil airspace, all aircraft (manned or unmanned) must comply with three rules to fly in the NAS; aircraft must be certified as airworthy, pilots/operators must be qualified to operate the aircraft in the appropriate classes of airspace, and flight operations must be in compliance with applicable regulatory guidance. In summary, all DoD UAS aircraft and operators are certified by the DoD in airworthiness and receive extensive training, and all applicable FAA rules and military department regulations must be followed for flight in the NAS (United States Department of Defense, 2011).

## IFR Traffic Determination in the New York Area

Before UAS requirements and concerns could be considered, an understanding of existing air traffic in the New York Terminal Area was required. To do this, an FAA approved New York

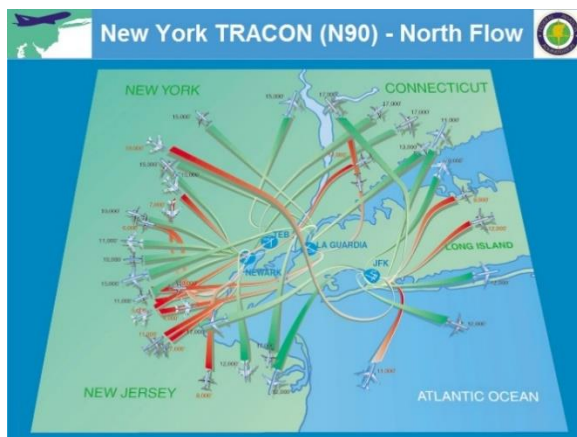


Figure 7. New York TRACON north flow approach patterns for KEWR, KTEB, KJFK, and KLGA.

Terminal Area Chart was taped to a wall. An overhead projector was aligned with the terminal area chart. Flightaware.com was then positioned over the chart, matching the scaling, which allowed aircraft transponder data to track position and altitude over the chart (Flightaware.com, 2014). This procedure was done for Newark Liberty International Airport, John F. Kennedy International Airport, and LaGuardia Airport. The

process was repeated for different runways used due to varying wind conditions. This produced a



North and South flow depiction with altitudes and distances. To verify the aircraft on the screen, liveatc.net was used to confirm flights via air traffic control communications (liveatc.com, 2014). The routes and altitudes were then validated by the Newark Liberty International Airport's Air Traffic Control Tower using a program dedicated to predicting air traffic routing when various runways are in use at the three major airports (Saverese, 2014).

The altitude and position data was then entered into Microsoft Excel. Also entered was the altitude and position data for Instrument Landing System approaches and GPS or Visual Approaches for each runway in use. This produced a graph of altitude versus distance from the airport. A polynomial approximation was used to validate computer modelling of the descent profile. A linear approximation was used to estimate a performance based approach as predicted by NextGen and to determine an average vertical speed. By comparing these graphs to the current procedures and airspace, optimization of the airspace was able to occur by changing the current method of holding altitudes by a majority of commercial aircraft in heavily congested airspace. After this comparison and data collection, UAS requirements and integration proposals were made to accommodate the known air traffic in the New York Terminal Area (United States Department of Transportation/Federal Aviation Administration, 2008). (See Appendix I for approach data charts and Appendix IV for New York Terminal Area arrival and departure routes.)

# UAS Airspace Design

## New York Terminal Airspace Design Concepts

During this study, four designs were proposed for unmanned aircraft systems integration into the New York Terminal Area. Each design was considered with current airspace and NextGen expectations. The concepts were then compared to each other using an objective alternative design matrix with weighted criteria. The highest output value was, according to the matrix, the best suited airspace design for UAS integration in the New York Terminal Area.

**Design 1** consisted of a UAS restricted zone over New York City and the surrounding airports created by connecting tangent lines from EWR class B SFC airspace, JFK class B SFC

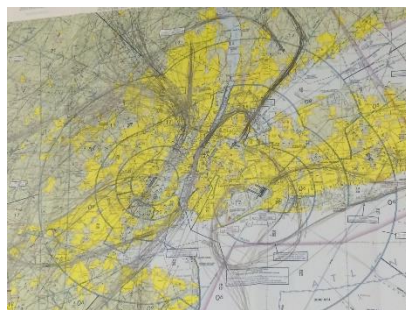
airspace, and LGA class B SFC airspace. In this region, UAS would be required to have a filed flight plan and constant communication with air traffic control. The three primary airports are prohibited to UAS traffic to accommodate arrivals and departures of scheduled air transportation. Teterboro Airport and Linden Municipal Airport, both of which are within the UAS restricted zone, would allow UAS traffic under the control of Teterboro tower, or New York Approach respectively. The Hudson River and East River exclusions would still be in effect with the addition of UAS traffic at 500 ft. or below over the water of either river. Any deviations from these exempted routes or altitude would require air traffic control approval. This is similar to the operation of current VFR flights in the Washington DC Special Flight Rules Area.

**Design 2** consisted of the same UAS restricted zone and procedures as Design 1 with the addition



*Figure 8. A sectional chart of the New York airspace with a projection of flightaware.com maps to trace incoming aircraft.*

of a GPS grid system. This grid system would be the only routes available to transient UAS traffic. The grid lines would connect UAS airports and areas of interest from Western New Jersey to Long Island. UAS would be required to operate within 1.5 nautical miles of this route and maintain specified altitudes by air traffic control. This plan allows better transient operations, but increases controller workload and may impact manned flight operations.



*Figure 9. A New York Sectional chart with traced south flow routes used for determining the most seamless method of UAS integration.*

**Design 3** was the prohibition of all UAS traffic within the lateral limits of the New York class B airspace. This plan was the most secure and safe, but failed to integrate UAS into the New York Terminal Area. This is consistent with current policy and acted as a control for the alternate design matrix.

**Design 4** consisted of the same UAS restricted zone as described in Design 1 and Design 2. However, UAS transient routes through the UAS flight restricted zone are established. There are 3 transient routes, two east to west, and one north to south. These routes are 3 nautical miles wide with 2000 ft. of altitude

between 3500 and 5500 ft. MSL. This altitude allows all IFR traffic to flow freely on current and expected routes without interference from transient UAS. The UAS within these routes would be operating without air traffic control guidance while transmitting a UAS transient transponder code. Any deviation from these transient routes will require air traffic control communication and authorization before the route deviation inside the UAS restricted zone. For routes, see Design 4 diagram.

These four designs were compared using the alternative design matrix and the previously listed weighted criteria. Through this analysis, Design 4 proved to be the best airspace design for UAS integration compared to the other three designs. By a margin of nearly 5%, this design allowed UAS access safely and efficiently, while minimizing impacts on manned flight operations and air traffic controller workload.

## Airspace Design Criteria

The airspace proposals for unmanned aircraft systems integration in the New York Terminal Area required a multifaceted analysis of the airspace, aviation safety, and national security. In the proposed designs, ten criteria were addressed which were all essential to successful UAS integration. The following list consists of the each criterion, what each criteria means, and the percentage assigned to it within the alternative design matrix:

**IFR Traffic Interference (15.00%):** Instrument Flight Rules (IFR) traffic consists of almost all traffic from New York City's three primary airports. This type of air traffic is always under the control of air traffic control throughout the entire flight. As this type of traffic makes up a majority of the world's scheduled air transportation, any UAS integration strategy would require minimal interference with projected NextGen arrival and departure procedures.

**Residential Impact (7.50%):** New York City and the surrounding suburban areas are heavily populated. Aircraft noise is a primary issue in the relationship between residents and a nearby airport. Some airports have noise abatement procedures in place to mitigate

the noise produced over residential areas. The integration of UAS would require a minimal increase in aviation related noise over populated areas under routes and around airports.

**System Safety (17.50%):** UAS technology must be able to operate safely with a very slim margin for operational errors. The UAS controller must have full, nearly instantaneous control of the aircraft as redundancy behind any autopilot software. Safety is defined as the mitigation of hazards to flight. By focusing on overall system safety, assets on the ground and in the air are protected through established procedures.

**System Security (10.00%):** System security is related to the mitigation of intentional threats related to UAS and the local area. UAS security within the system involves the protection of the flight control and communications data link from the ground station to the flight system. Security also relates to the national security assets in the New York Terminal Area, such as New York City landmarks, major airports, commercial ports, and high capacity events. A more secure system is able to prevent most threats due to system design and specific procedures.

**VFR Traffic Alterations (7.50%):** Visual Flight Rules traffic (VFR) consists of small aircraft and helicopters operating on a basis of see and avoid. This allows more freedom in movement and operations while lessening the burden of responsibility on air traffic control. Within Class B airspace, such as that which surrounds New York City, VFR traffic must be in contact with air traffic control. UAS would be required to give way to VFR aircraft as manned flight is a priority to unmanned operations.

**Continuity with Existing System (10.00%):** The existing airspace and air traffic control network is essential to the continuation of safe practices for all aircraft. NextGen will only alter certain flight routes while leaving the majority of other flight operations unchanged. By ensuring continuity with the existing system, a safe and efficient transition to UAS airspace access can be ensured.

**UAS Airport Access (7.50%):** Unmanned aircraft systems may need to be restricted to certain airports to minimize the interference with the air transportation network. These restrictions may also increase system security. However, as restrictions are imposed,

freedom of UAS operation is reduced. By allowing access to nearby airports, UAS has a better opportunity to expand when UAS integration occurs.

**Emergency Procedures (2.50%):** Emergency procedures refer to the amount of free space there is within the operational area of the UAS system. If a failure was to occur, how would each failure be mitigated? In most cases, redundant systems will be activated to prevent dangerous situations from developing. While this criterion was given a relatively low value, emergency operations are essential to this process. The overall integration of UAS will require specific emergency procedures for each type of aircraft system and operation.

**Air Traffic Control Responsibility (12.50%):** Air traffic control has a limited number of resources through their highly trained controllers. While automation will reduce future workload, increased volume will strain the system and stress controllers as they maintain closer separation between aircraft. The integration of UAS into the national airspace system will increase controller workload further unless they can be operated safely without having to maintain positive control through air traffic control.

**Airspace Changes Required (10.00%):** The New York Terminal Area has complex airspace due to a variety of existing traffic and operations unique to the New York City area. By minimizing the amount of change required to the current airspace, the seamless operation of existing traffic can continue through UAS integration. This will allow integration much sooner than drastic airspace redesign and allows focus to remain of UAS requirements without altering the flight profiles of current operations.

Through these criteria, the integration of UAS in the New York Terminal Area can be quantified; allowing objective comparison between multiple airspace design proposals. The produced alternate design matrix compared all designs on a weighted scale with the highest scoring design being the optimal design for integration of UAS in the New York Terminal Area. (See Appendix II for full alternate design matrix.)

# UAS Operational Airspace for the New York Terminal Area

The final design for UAS airspace in the New York Terminal Area is as follows:

**Lateral Limits of Class B Airspace:** All UAS operations within the lateral boundaries of the New York Class B Airspace below 18,000 ft. MSL must have, in addition to the requirements of CFR 14 Part 91.213, a mode C transponder, ADS-B system, GPS navigation equipment, sense and avoid technology, and a dedicated link to a ground operator.

Unless operating in an Exclusion Zone (see Hudson and East River Exclusions, Teterboro Exclusion, and Linden Exclusion) or a UAS Transient Route (see UAS Transient Routes), all UAS entering or conducting operations within the lateral limits of the New York Class B airspace must be in contact with air traffic control and squawking a discrete transponder code.

Operations in this airspace are similar to those of VFR aircraft in the Washington DC Special Flight Rules Area (SFRA).

**New York UAS Flight Restricted Zone (UFRZ):** The New York UAS Flight Restricted Zone is defined as the airspace surrounding EWR, JFK, and LGA up to 10 nautical miles radius from either airport. This zone includes New York City and the Verrazano Bridge. All UAS flight, except exclusions and UAS Transient Routes, in this area is prohibited unless a special flight plan is filed for the flight and a TSA background check has occurred. This zone is established for safety and national security. Any flight operations in this airspace by unauthorized UAS may lead to a use of force.

**UAS Transient Routes (UTR):** Unmanned aircraft system transient routes are corridors through the New York Terminal Area which allow UAS passage through the controlled airspace without air traffic control communication. The UTR corridor is 3 nautical miles wide, 1.5 nautical miles on either side of the center line, and ranges 2,000 ft. in altitude. The UTRs through the New York Terminal Area are set between 3,500 ft. MSL and 5,500 ft. MSL. All UAS in the UTRs must maintain separation via sense and avoid technology. Any deviation from the UTR into the lateral limits of the New York Class B will require air traffic control authorization and a discrete transponder code. Any deviation into the UFRZ will require a previously filed special flight plan. All UAS within the UTRs must transmit a transponder code of 1300 to identify it as a non-



participating aircraft within the UTR. Three UTRs were created in the New York Terminal Area; Palisade and Atlantic, East/West routes, and Freedom, a North/South route.

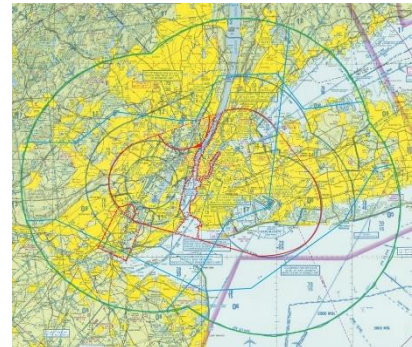
**Palisade UTR:** Eastbound traffic at 4,500 ft. Westbound traffic at 3,500 ft. course travels from Oyster Bay, NY towards LGA, continuing around the 11 nautical mile LGA DME arc to New Jersey. Then, proceed direct KTEB, direct KCDW, direct KMMU, then true course of 270 until clear of lateral limits of New York Class B airspace.

**Atlantic UTR:** Eastbound traffic at 4,500 ft. Westbound traffic at 3,500 ft. Direct KFRG, direct Jones Beach, direct Highlands, direct Perth Amboy, and direct SBJ on VOR TO 095 radial.

**Freedom UTR:** Northbound traffic at 5,000 ft. Southbound traffic at 4,000 ft. From KHPN, direct KJFK, direct Floyd Bennett Field, direct Sandy Hook, TO COL VOR 047 radial.

**Hudson River Exclusion:** UAS travelling within the lateral boundaries of the Hudson River and Upper New York Bay through the UFRZ are permitted to operate at or below 500 ft. UAS would be required to follow the guidelines in CFR 14 Part 93 New York Special Flight Rules Area with the new altitude restriction. Any change in altitude or lateral deviation would require air traffic control authorization. All UAS in the Hudson River Exclusion are required to squawk “1311” to identify the UAS as Hudson River Exclusion traffic.

**East River Exclusion:** UAS travelling within the lateral boundaries of the East River and Upper New York Bay through the UFRZ are permitted to operate at or below 500 ft. UAS would be required to follow the guidelines in CFR 14 Part 93 New York Special Flight Rules Area with the new altitude restriction. Any change in altitude or lateral deviation would require air traffic control authorization. All UAS in the East River Exclusion are required to squawk “1322” to identify the UAS as East River Exclusion traffic.



*Figure 10. Chart with final airspace design outlines. (For larger image, see Appendix III)*

**Teterboro Exclusion:** Teterboro Airport and the Teterboro Class D airspace are exempt from the conditions of the UFRZ. However, flights to and from the UFRZ from TEB must have an active special flight plan and communication with air traffic control.



**Linden Exclusion:** Linden Municipal Airport and the surrounding area allow UAS flight operations below 1200 ft. MSL within the UFRZ. Any flight into the UFRZ from this area requires an active special flight plan and air traffic control communication and authorization.

**EWR UAS Altitude Restriction Area:** All UAS operations, with the exception of the Atlantic UTR, must remain below 1200 ft. MSL over a rectangle 5 nautical miles wide oriented parallel with a magnetic course of 039 extending from the approach ends of EWR runway 4L and 4R. The northern bounder of this restriction is Linden Municipal Airport with the center of the southern end terminating at the Driscoll Bridge (Garden State Parkway at the Raritan Bay).

**Operator Qualifications:** All UAS operators must hold at least a private pilot certificate with an instrument rating and a UAS flight endorsement. Commercial operations will require at least a commercial pilot certificate with an instrument rating and a UAS flight endorsement.

**UAS Airport Access:** All UAS would be prohibited from taking off or landing at Newark Liberty International Airport, John F. Kennedy International Airport, and LaGuardia Airport. (See Appendix III for full-sized final UAS airspace design.)

## Additional Cost to NextGen

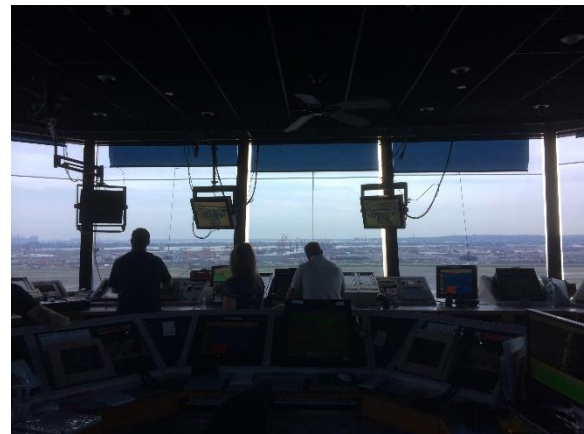
NextGen is expected to cost 40 billion dollars in development through 2020, with 11 billion dollars allotted to NextGen programs between 2011 and 2015. The NextGen system is expected to save 22 billion dollars every year over the current airspace operational structure. While the addition of UAS into the National Airspace System is factored into the current NextGen budget and strategy, this assumption is based on an automated UAS infrastructure. Although some tasks can be completed autonomously, UAS autonomous software is not yet at a level where it can operate safely in a complex, high air traffic density location such as New York City. All aircraft will have to be controlled by a dedicated remote operator while in the vicinity of New York airspace. This increases the cost per UAS for commercial operations by \$25,000 per year, the median salary of a commercial pilot at a regional airline. For the FAA, the increase in controller workload, due to both future manned and unmanned traffic, will require additional controllers. However, the number

of new controllers required will be reduced due to the introduction of new automated systems for manned air traffic. If the assumption that UAS will increase overall workload over NextGen expectations is made, six new controllers will be required to operate the UAS airspace in the New York Terminal Area. This is based on one controller in each primary airport tower and three controllers dedicated to UAS in TRACON. This would increase the FAA expenditure approximately \$736,542 per year (the sum of six average New York air traffic controller salaries). While this seems excessive, this estimate is a high approximation, and includes training for all newly hired air traffic controllers. The lowest cost model is Design 3, which would require no additional air traffic controllers in addition to NextGen projections, decreasing additional cost to the FAA to \$0. However, this defeats the purpose of NextGen and this project, the integration of unmanned aircraft systems in the New York Terminal Area. While Design 4 is more complex than the other three designs, it allows access better access with similar additional cost to NextGen (Commercial Aviation Safety, 2012).

## Conclusion

In conclusion, the integration of unmanned aircraft systems into the national airspace system is inevitable, as UAS technology continues to grow and find new purposes and applications. While the airspace surrounding New York City is some of the busiest in the world, UAS integration is possible based on predicted technology and traffic flow. The Federal Aviation Administration and the

Department of Defense have pioneered the integration of UAS into domestic airspace, but never addressed the complexities of intricate terminal airspace, such as the New York Class B airspace. By analyzing Department of Defense integration plans and FAA Next Generation Air Transportation Network (NextGen) strategies, the ability to seamlessly integrate UAS in the New York Terminal Area became possible. Upon further analysis of current air traffic patterns, more efficient use of the airspace could be proposed. UAS integration in the New York Terminal Area has the potential to unlock new commercial markets



*Figure 11. A photo of Newark Liberty International Airport air traffic controllers busy at work.*

and advance certain scientific endeavors, such as a weather surveillance UAS to collect data for Goddard Institute for Space Sciences analysis. Through UAS routing, air traffic controllers will not experience a major increase in workload. Safety and efficiency will be increased due to the majority of UAS traffic remaining clear of known manned flight operations areas. By proposing a safe and effective plan for UAS integration in the New York Terminal Area now, the introduction of UAS in the near future, by 2025, becomes a major possibility. The possibility of UAS integration allows technological advancement and economic growth in a seemingly stagnant aviation industry.

# Appendix I

## Approach Data Charts

### EWR- Newark Liberty International Airport

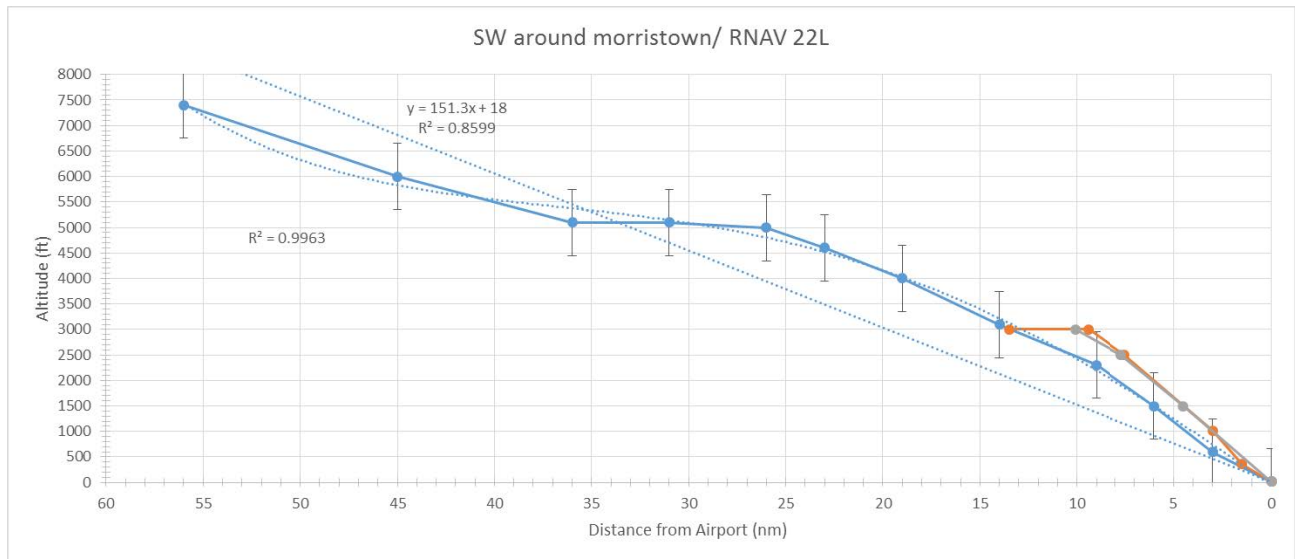


Figure 1. 22L South Flow

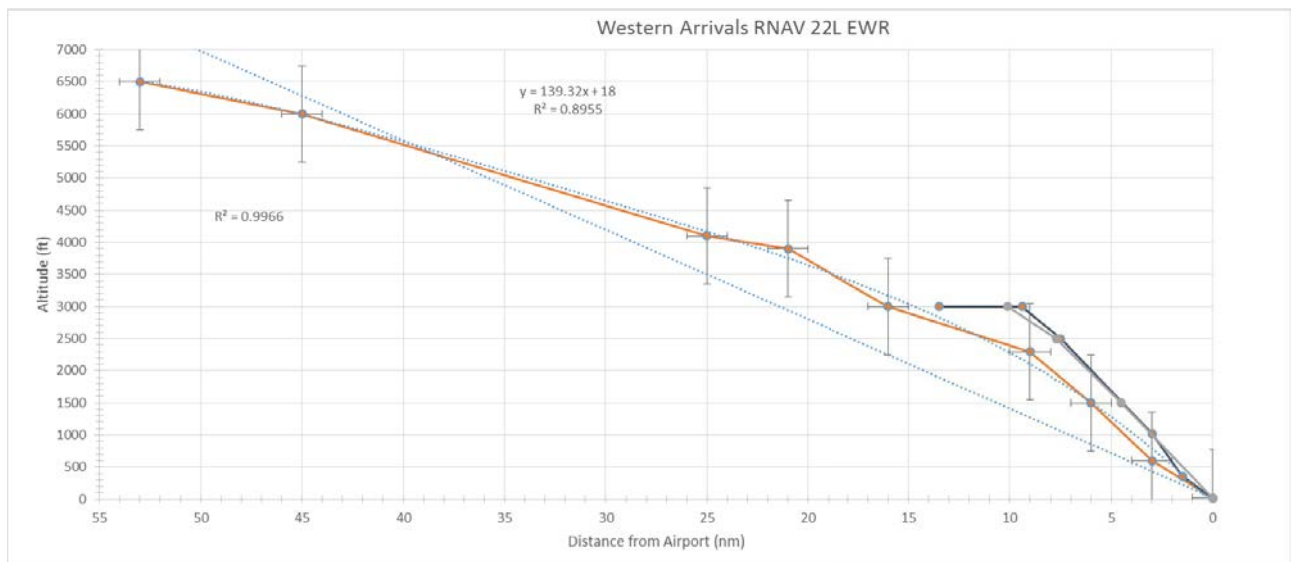


Figure 2. 22L South Flow

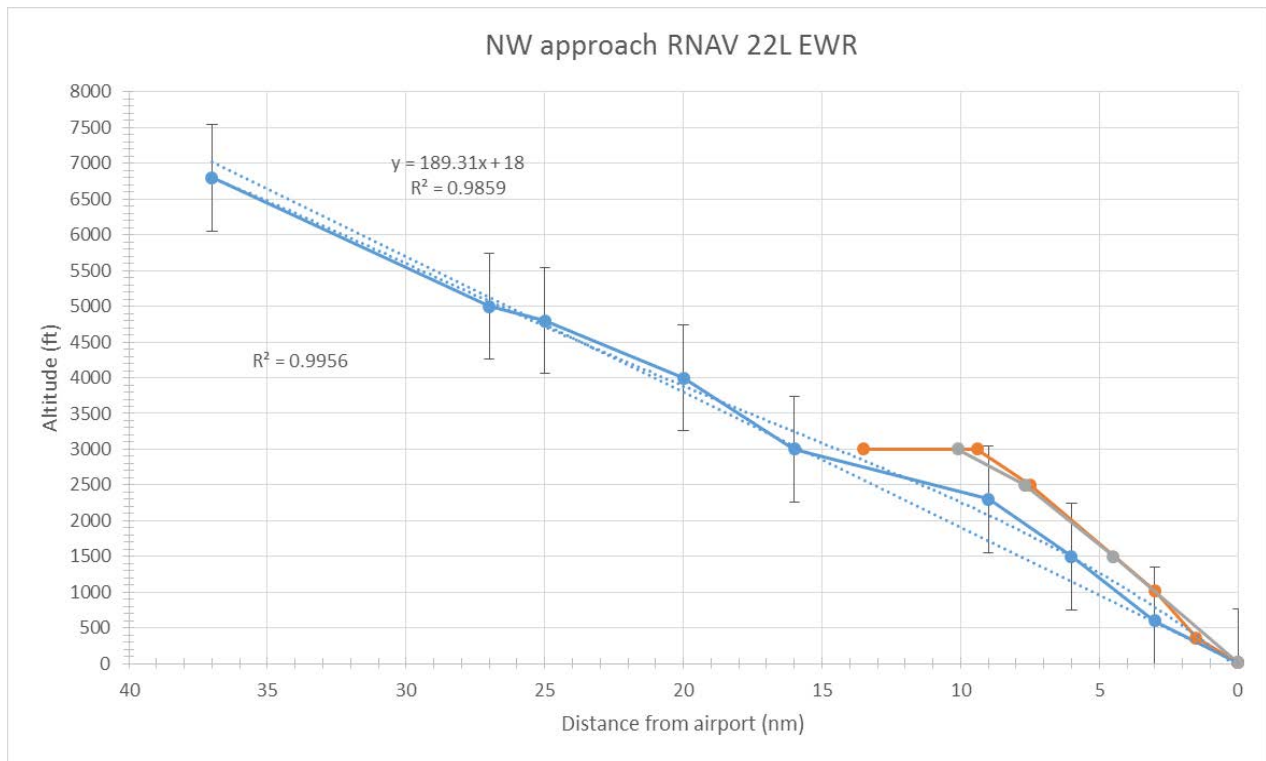


Figure 3. 22L South Flow

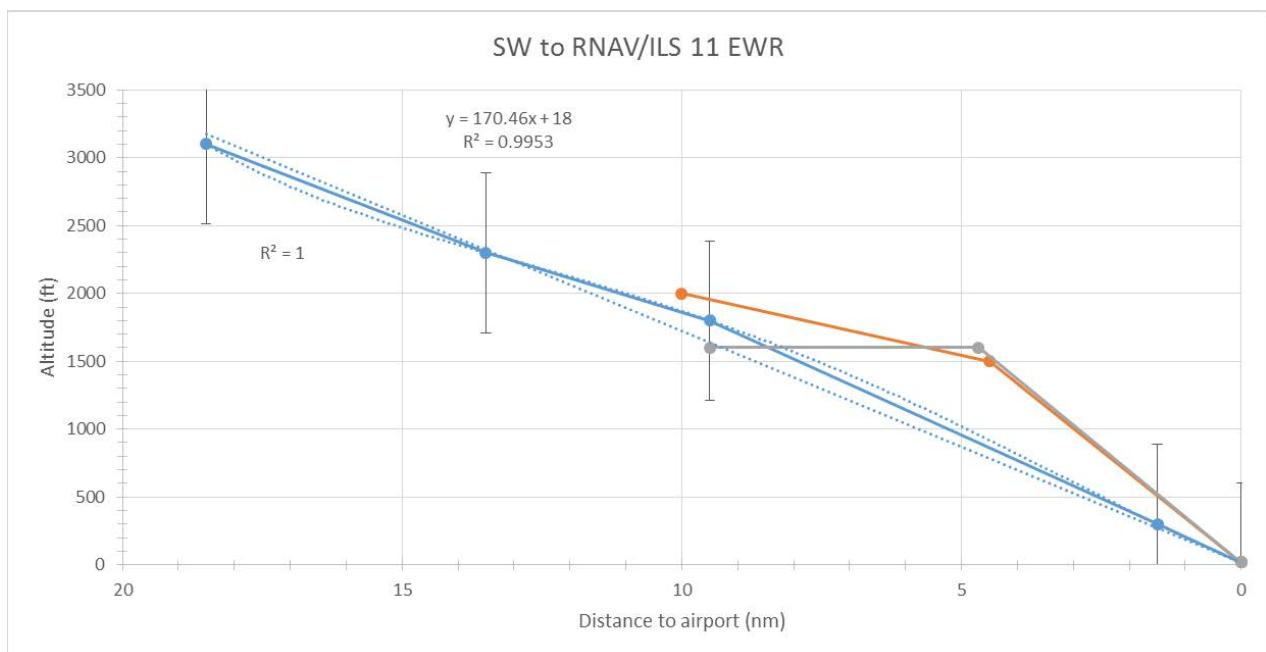
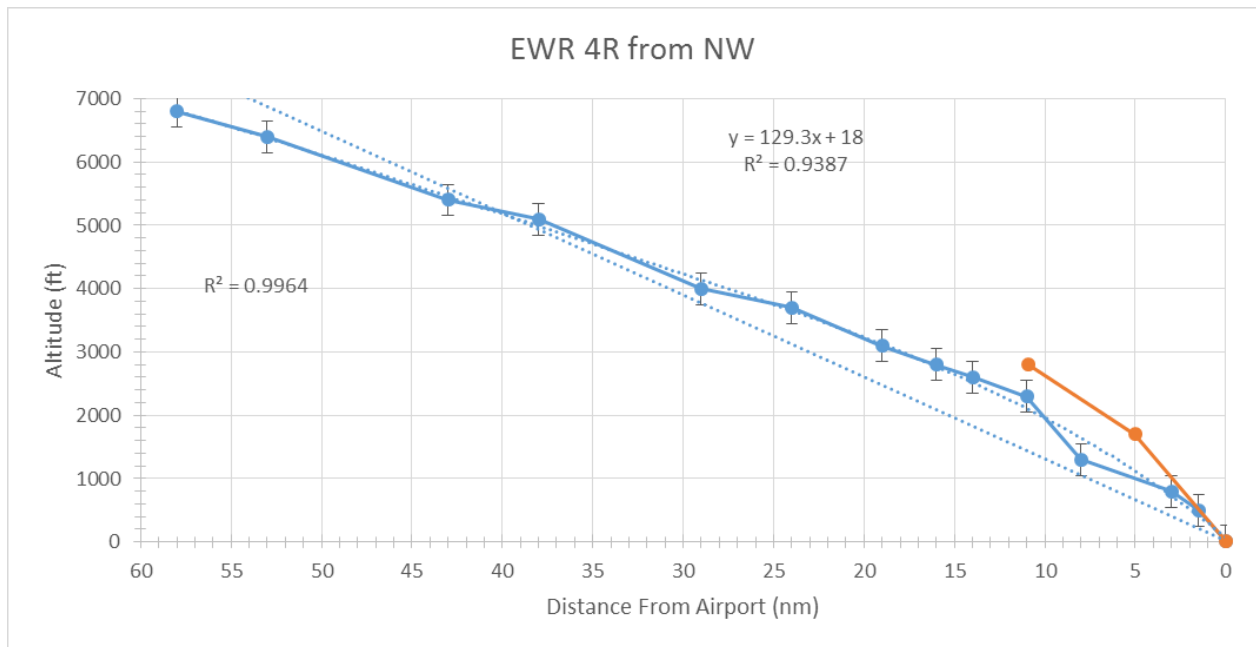
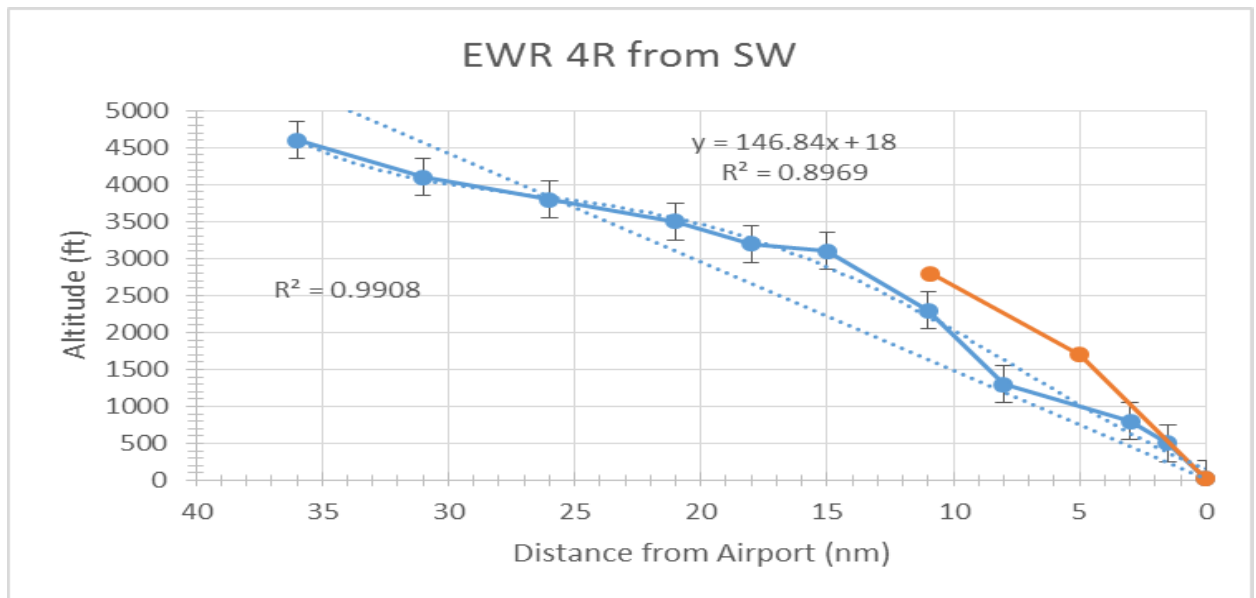


Figure 4. 11 South Flow



*Figure 5. 4R North Flow*



*Figure 6. 4R North Flow*

## JFK- John F. Kennedy International Airport

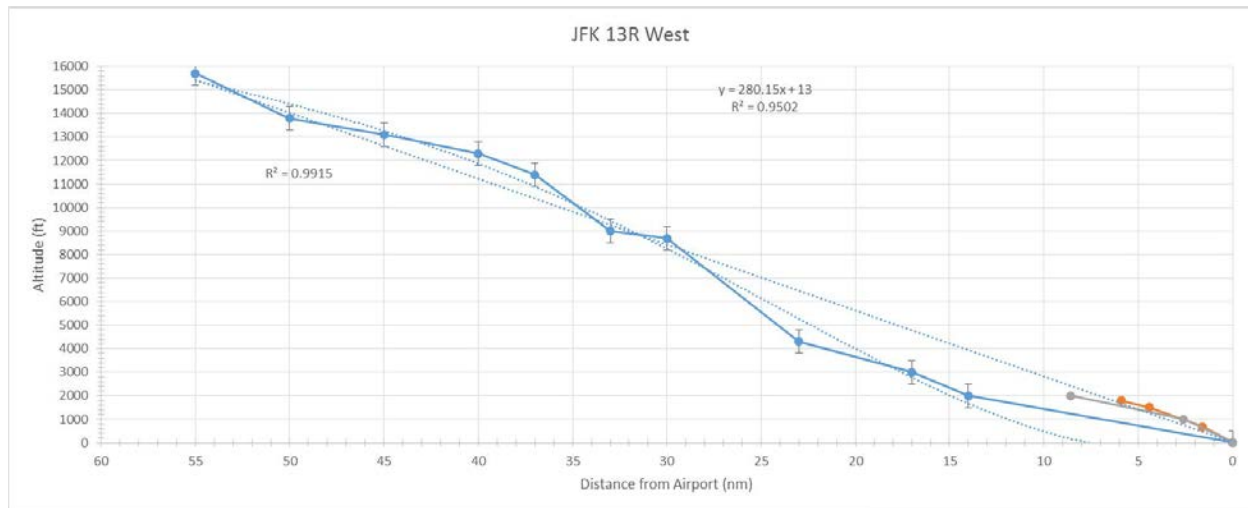


Figure 7. 13R South Flow

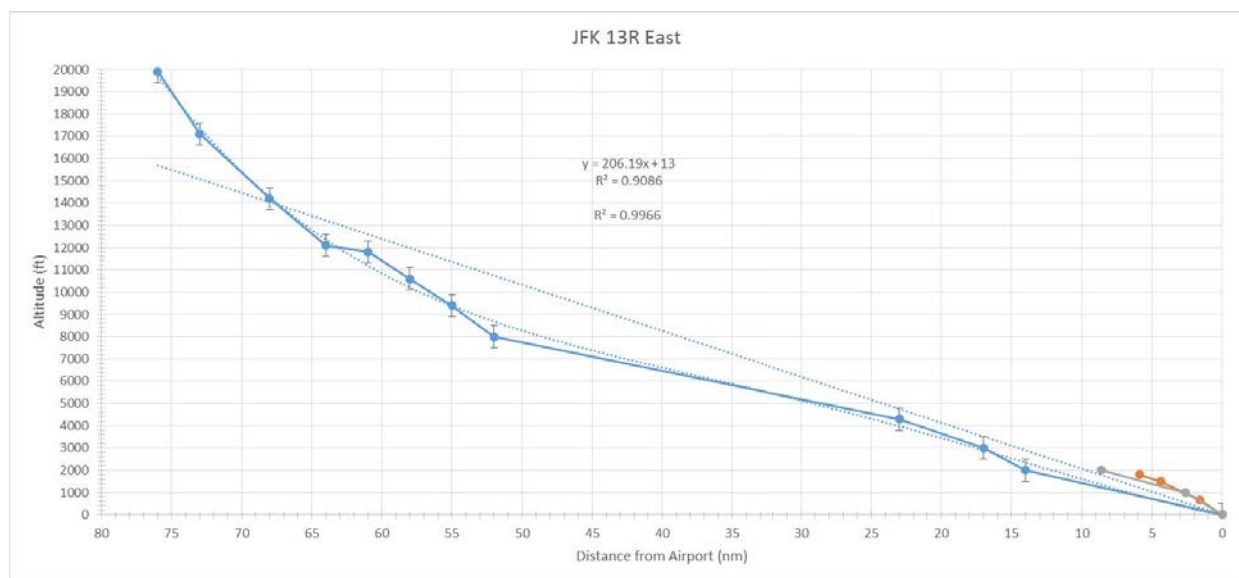
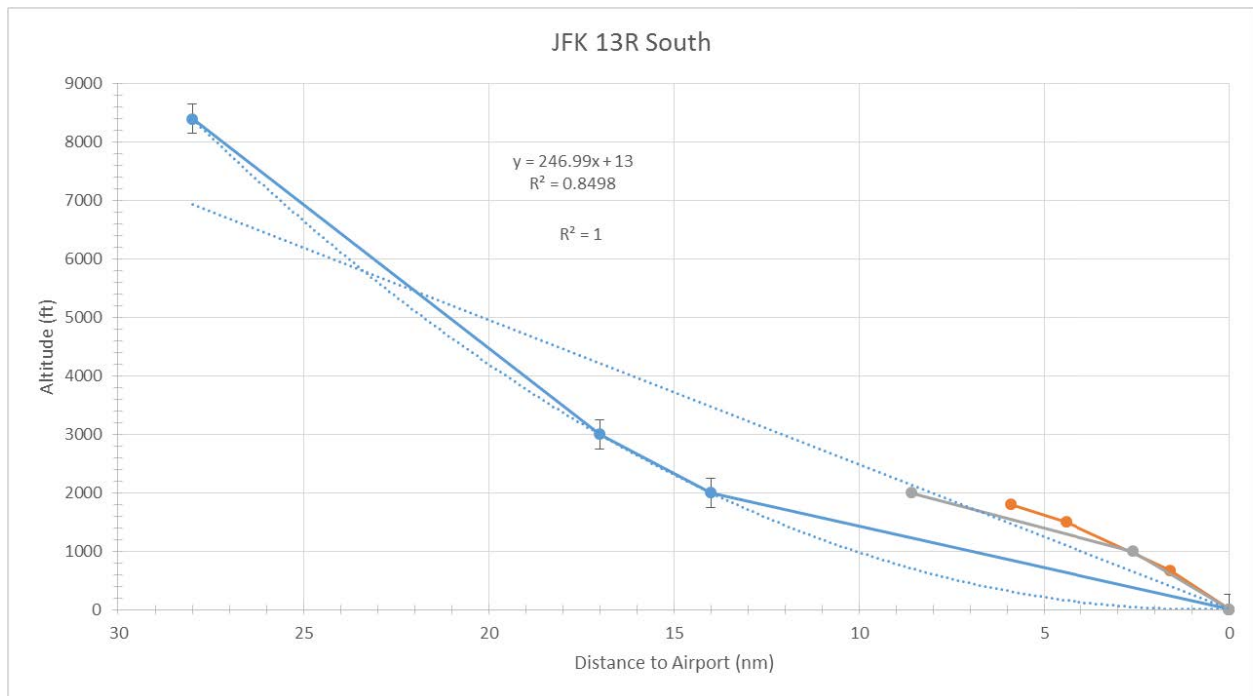
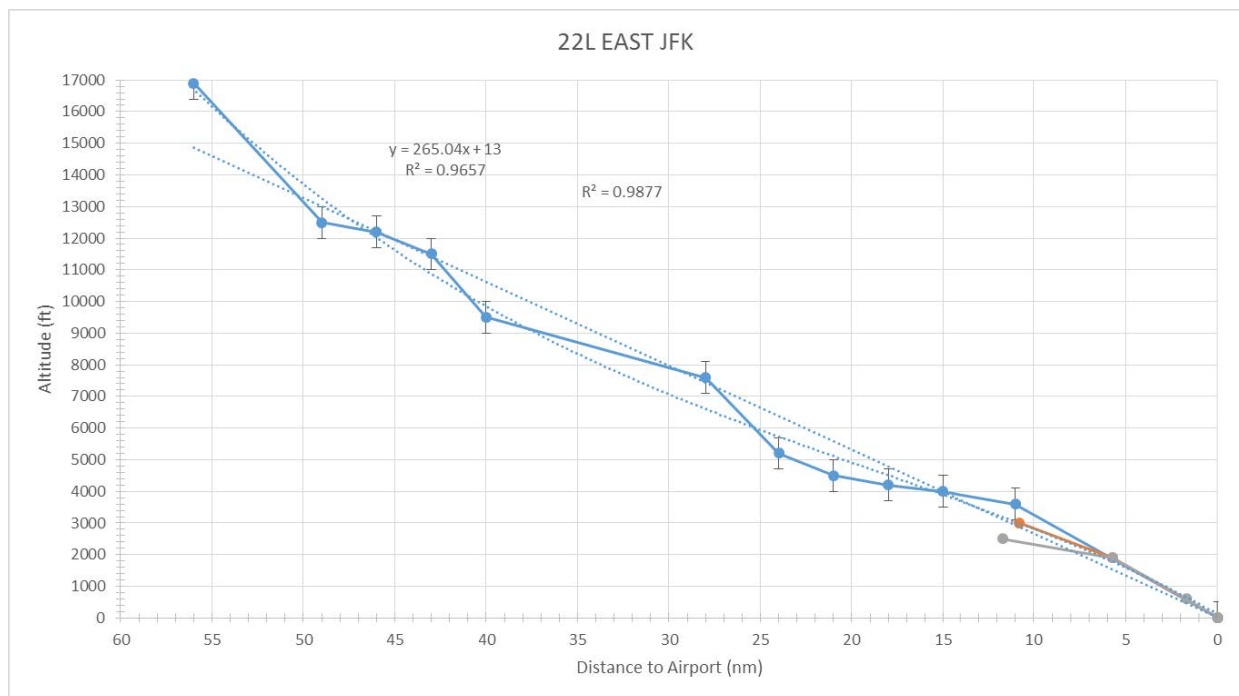


Figure 8. 13R South Flow





*Figure 9. 13R South Flow*



*Figure 10. 22L South Flow*

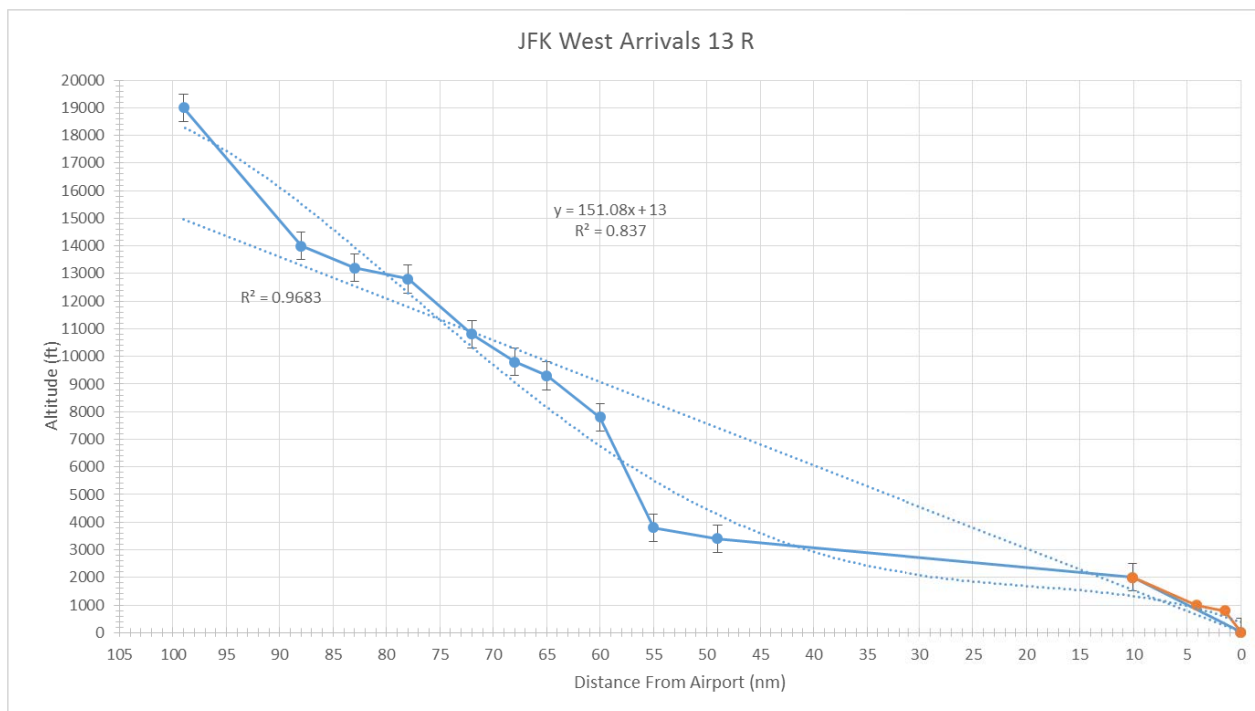


Figure 11. 13R North Flow

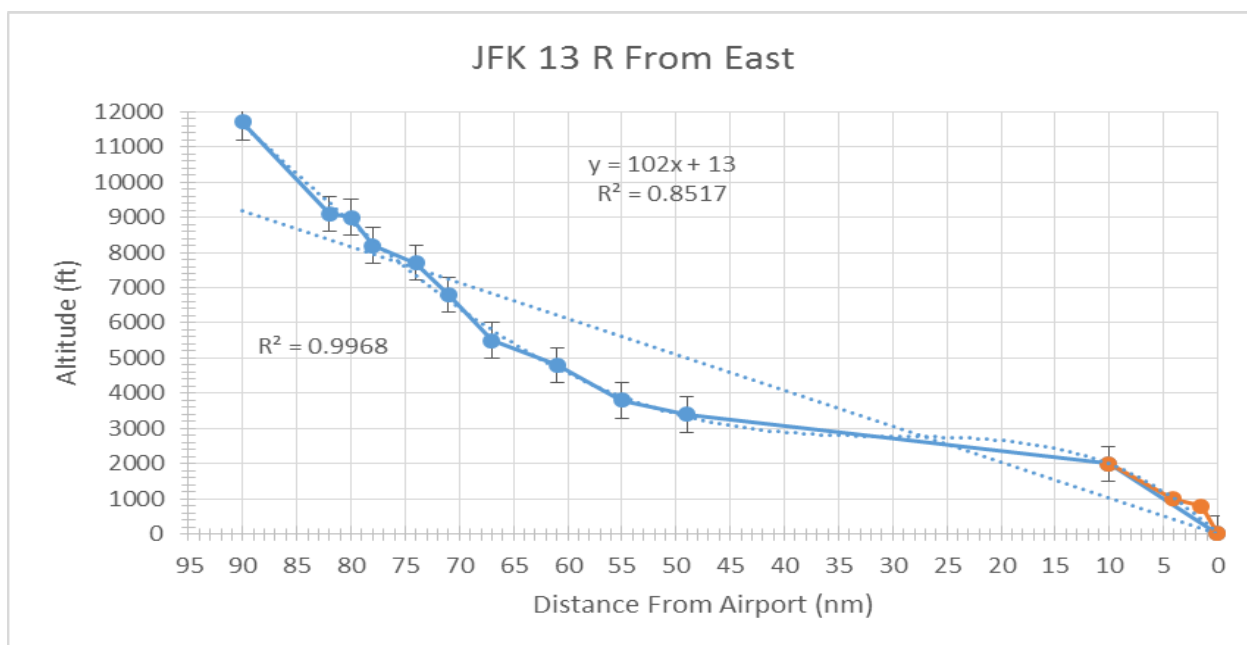


Figure 12. 13R North Flow

## LGA- LaGuardia Airport

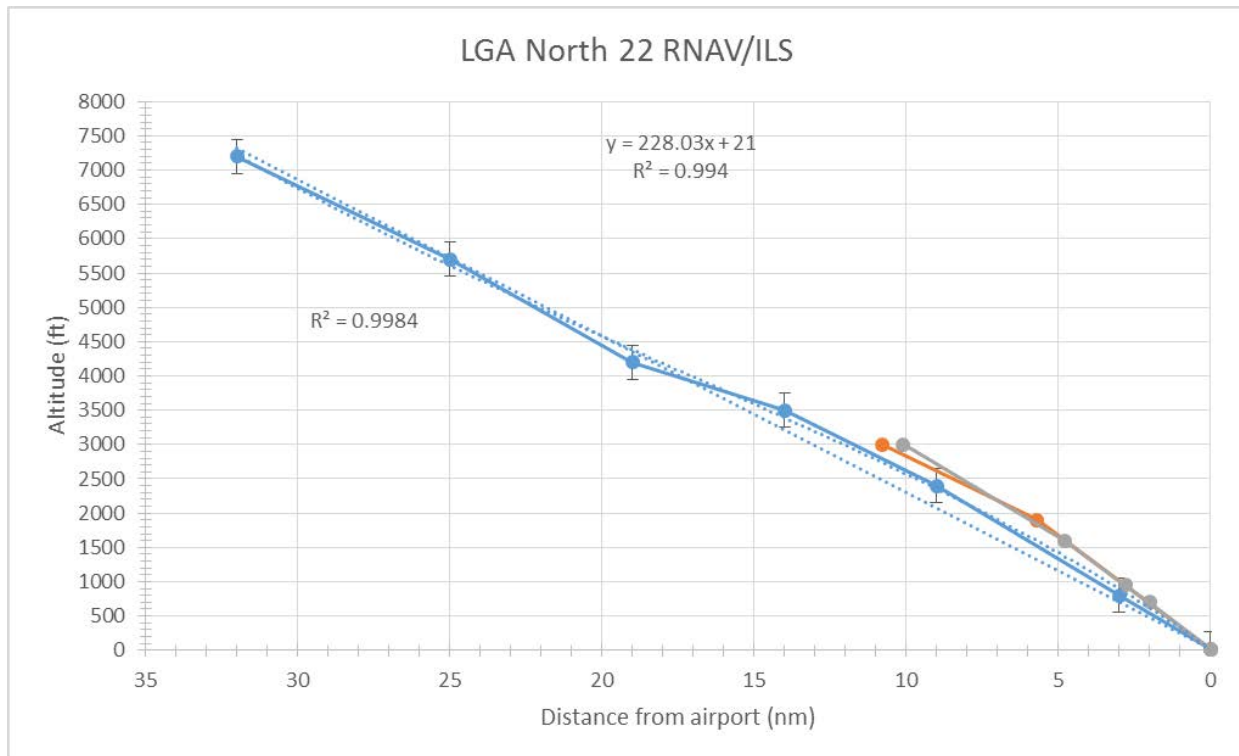


Figure 13. 22 South Flow

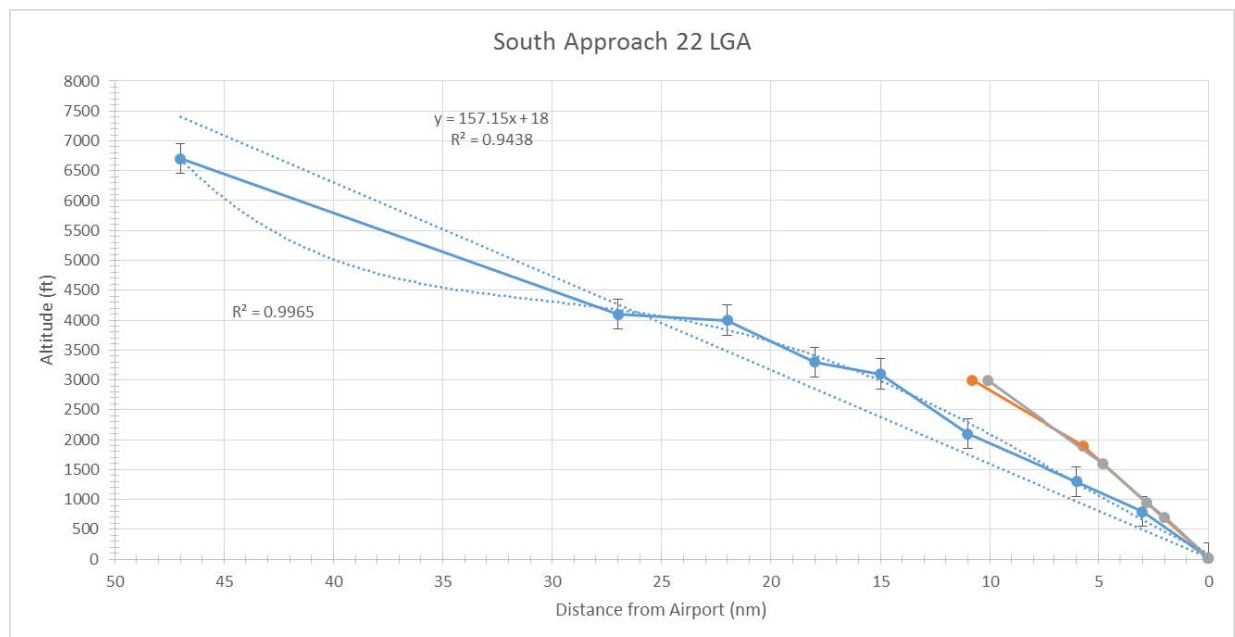
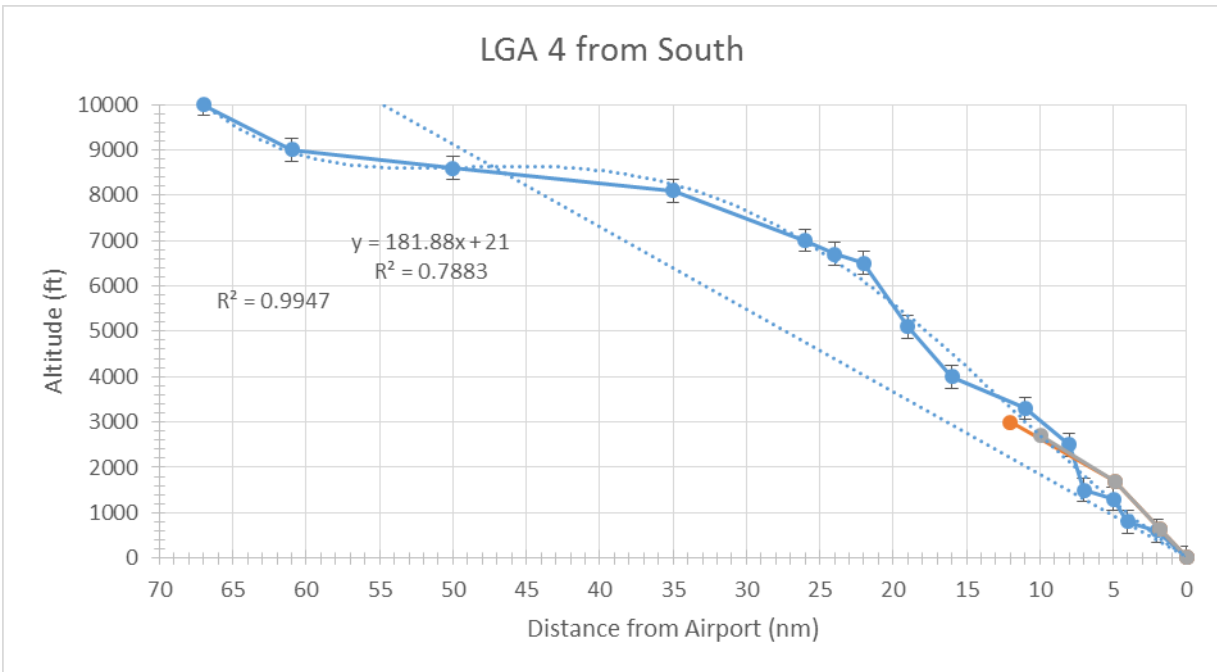
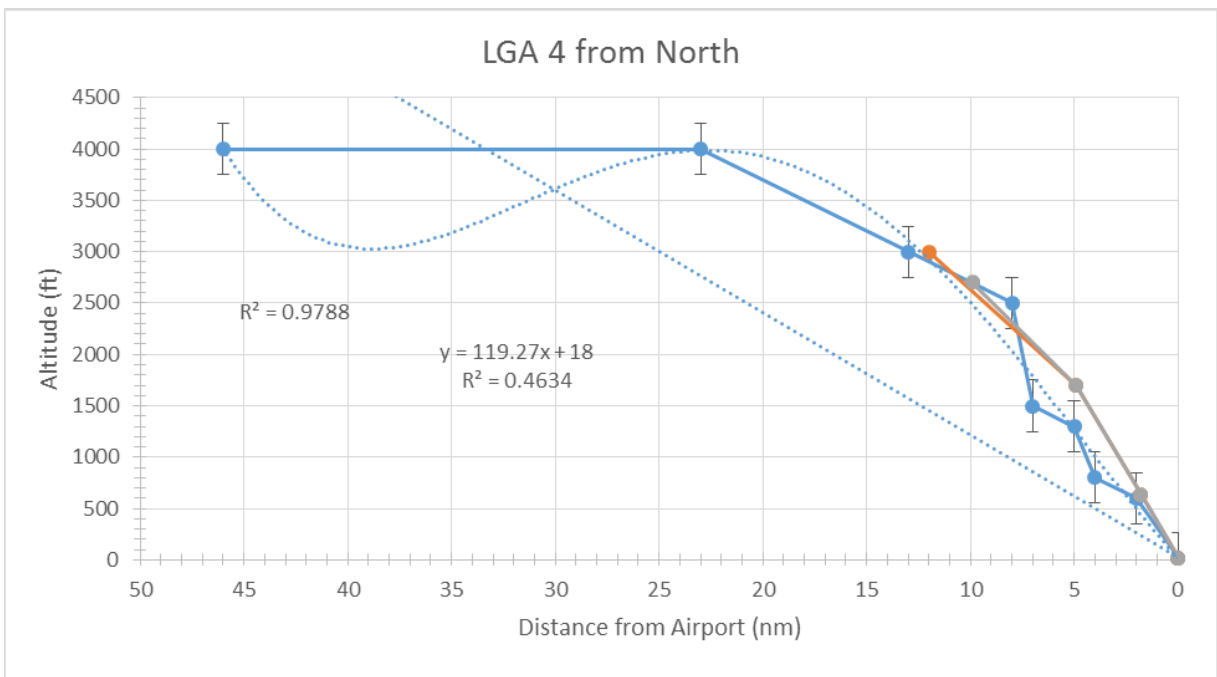


Figure 14. 22 South Flow



*Figure 15. 4 North Flow*



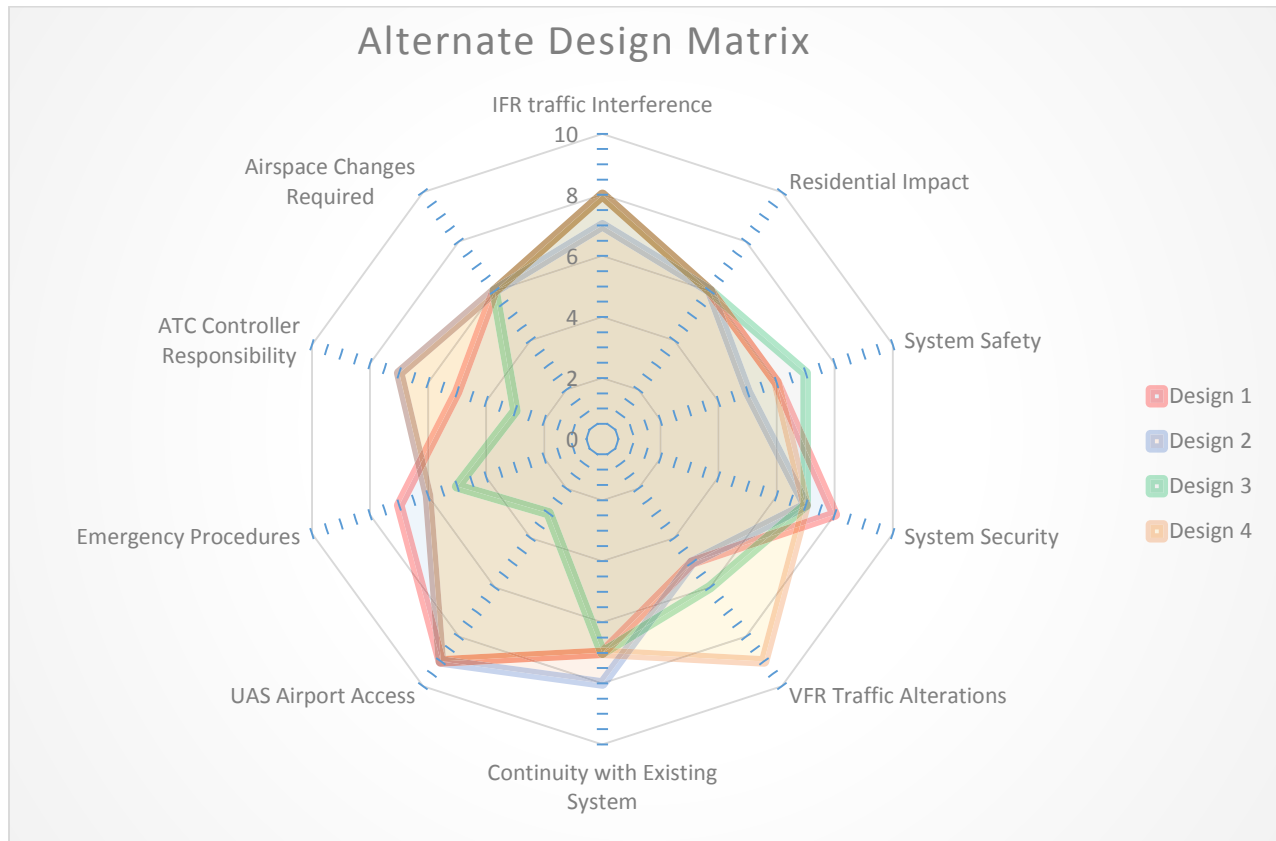
*Figure 16. 4 North Flow*

# Appendix II

## Alternate Design Matrix

Alternative Design Matrix									
		Design 1		Design 2		Design 3		Design 4	
Criteria	weight	rating	score	rating	score	rating	score	rating	score
IFR traffic Interference	15.00%	8	1.2	7	1.05	8	1.2	8	1.2
Residential Impact	7.50%	6	0.45	6	0.45	6	0.45	6	0.45
System Safety	17.50%	6	1.05	5	0.875	7	1.225	6	1.05
System Security	10.00%	8	0.8	7	0.7	7	0.7	7	0.7
VFR Traffic Alterations	7.50%	5	0.375	5	0.375	6	0.45	9	0.675
Continuity with Existing System	10.00%	7	0.7	8	0.8	7	0.7	7	0.7
UAS Airport Access	7.50%	9	0.675	9	0.675	3	0.225	9	0.675
Emergency Procedures	2.50%	7	0.175	6	0.15	5	0.125	6	0.15
ATC Controller Responsibility	12.50%	5	0.625	7	0.875	3	0.375	7	0.875
Airspace Changes Required	10.00%	6	0.6	6	0.6	6	0.6	6	0.6
Total	100%		6.65		6.55		6.05		7.075

Figure 1. Alternate Design Matrix Chart

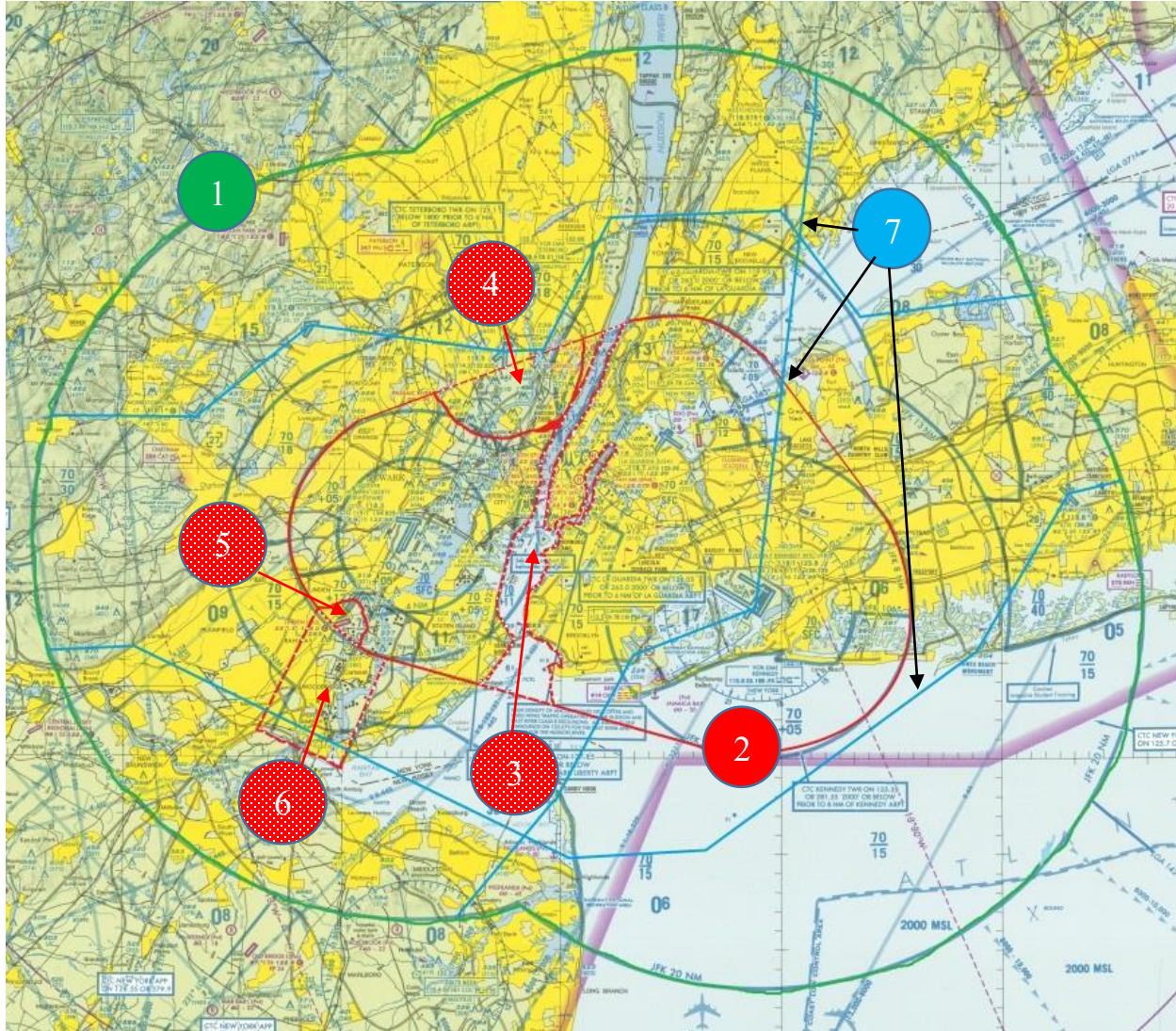


*Figure 2. Alternate Design Matrix Radar Chart*



# Appendix III

## Final UAS Airspace Design



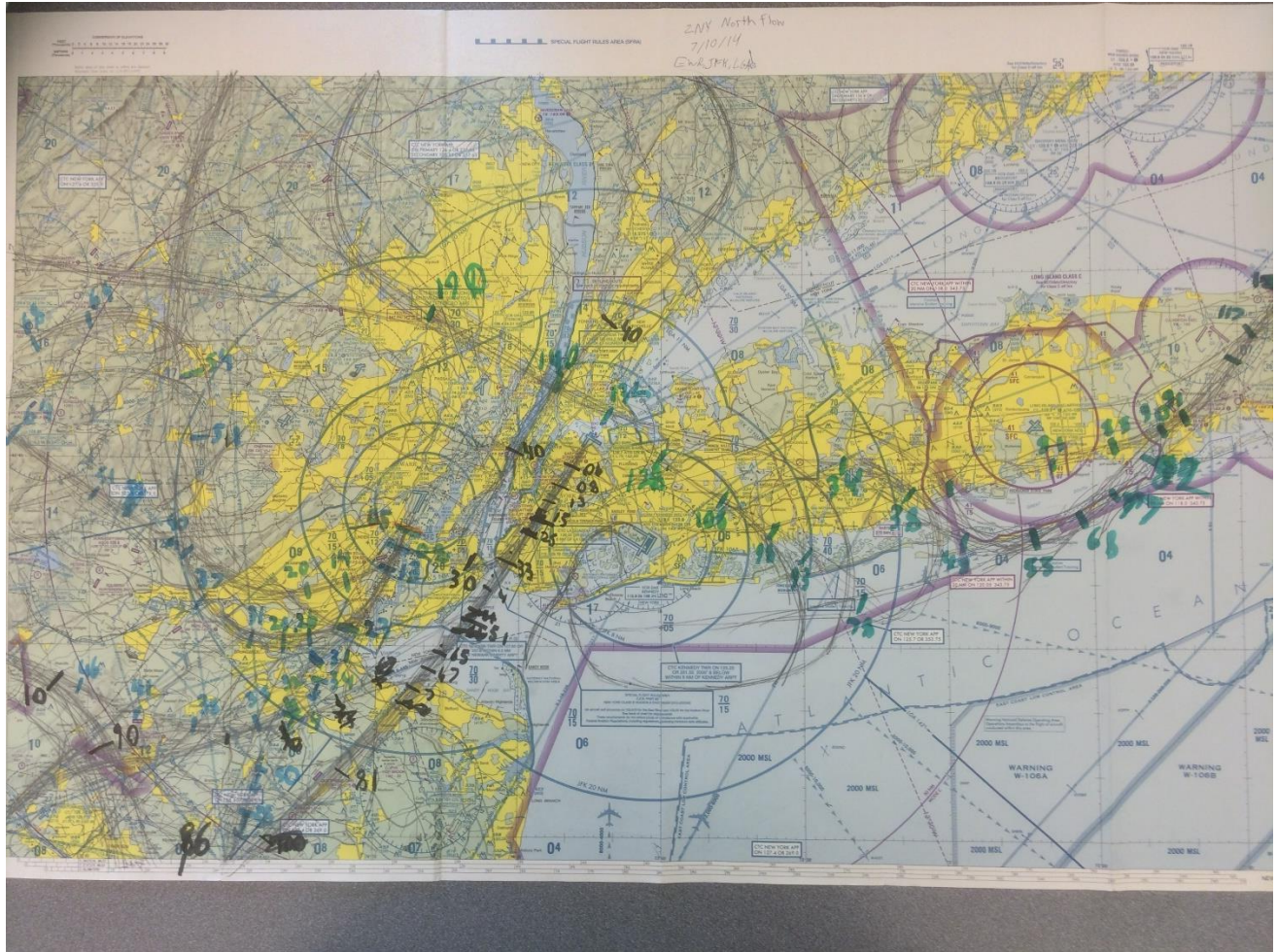
### UAS Airspace Components:

1. Lateral Limits of New York Class B Airspace
2. UAS Flight Restricted Zone (UFRZ)
3. Hudson River and East River Exclusions
4. Teterboro Airport Exclusion
5. Linden Municipal Airport Exclusion
6. EWR approach Altitude Restriction Area
7. UAS Transient Routes (UTR)



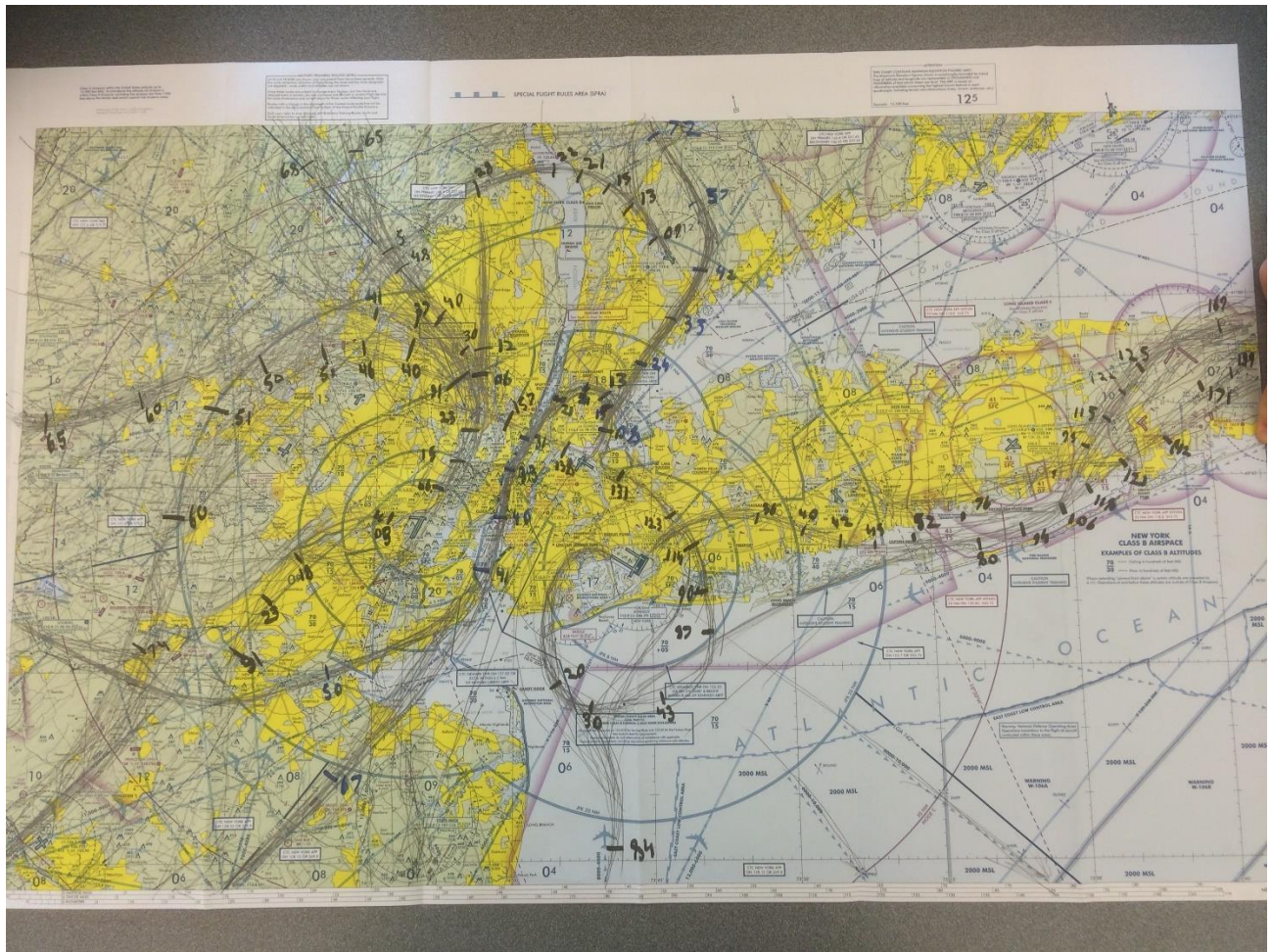
# Appendix IV

## New York Terminal Area Arrival and Departure Routes (Sketched)



*Figure 1. EWR, JFK, LGA North Flow Approaches*





*Figure 2. EWR, JFK, LGA South Flow Approaches*

# Appendix V

## List of Acronyms

**UTR**-UAS Transient Routes

**UFRZ**-UAS Flight Restricted Zone

**IFR**-Instrument Flight Rules

**VFR**- Visual Flight Rules

**UAS**- Unmanned Aerial System

**UAV**- Unmanned Aerial Vehicle

**NAS**- National Airspace System

**DoD**- Department of Defense

**FAA**- Federal Aviation  
Administration

**COA**-Certificate of Authorization

**NextGen**- Next Generation Air  
Transportation System

**TFR**- Temporary Flight Restrictions

**MSL**- Mean Sea Level

**ADS-B**- Automatic Dependent  
Surveillance- Broadcast

**NASA**- National Aeronautics and  
Space Administration

**TRACON**- Terminal Radar Approach  
Control Facilities

**SFC**- Surface

**CFR**- Code of Federal Regulations

**GPS**-Global Positioning System

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